Quick and clean: Dirty bomb scenarios evaluated with the decision support system LASAIR

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Abstract

Emergency authorities in the context of radiation safety have to take into account that they might have to handle a “dirty bomb” or Radiological Dispersion Device (RDD) scenario. Even not being very likely it is necessary to be prepared for such a thread.

A lot of problems might come up with such a scenario; less might be known about radionuclides or explosive mass, realistic simulation of the atmospheric dispersion still is a challenge. One problem in such a scenario here is the initial cloud after an explosion. The development of such a cloud is a process that is dominated by thermodynamics and the momentum initiated by the explosive material. Up to now no meteorological turbulence parameterisation is known that could deal with this problem. A simple solution therefore has been derived from explosion experiments by gaining a photogrammetrical survey of the initial cloud; it has been applied successfully in the past for such kind of atmospheric dispersion modelling.

Another problem in a dirty bomb scenario is the possible transformation of a radionuclide substance with a distinct physical form (metallic, ceramic, liquid, powder) into fragments or aerosols after an explosion. An intensive research programme has been conducted to answer these questions.

Some preliminary results and its influence from both initial volume and aerosol spectra to a decision support system based on Lagrangian particle simulation (LASAIR) are discussed.

1. INTRODUCTION

In present times there still is a fear that terrorists might aim with an act of violence against the population in an urban environment to enforce illegal demands. An often discussed possibility is to deploy or disperse explosive material combined with radioactive substances somewhere in public areas. This is called a “dirty bomb-” or an RDD- (radiological dispersive device) scenario.

In such a case it is essential to get a clear picture of the potential threat as quickly as possible. This means that the possible radioactive concentration in the surrounding areas and the contribution to the pathways which lead to the exposure

of the population can be assessed and counter measures can be recommended. This will be achieved e.g. by a simulation of the explosion and the dispersion of the radioactive material.

Some of the most sensitive input parameters for atmospheric dispersion in such a case are source term after an explosion and aerosol spectra for the inhalation of radionuclides. Intensive work on providing these parameters for atmospheric dispersion models have been undertaken in the past and lead now to the successful application. Both procedures are discussed hereafter.

2. INITIAL CLOUD PARAMETERISATION FOR DISPERSION MODELLING FROM EXPLOSIVE EXPERIMENTS

To run a dispersion model properly information about the source term has to be provided as an input. Usually dispersion models can use a point, a line, an area or a volume source term. However in literature only a few references are listed for source terms after an explosion. [1, 2, 3, 4].

Therefore a parameterisation was developed from two series of explosion experiments with a range of 0.5 - 100 kg PETN that have been conducted at German Army test sites in 2003 and 2007. The shape of the cloud after the explosion has been calibrated after several series of explosions by means of two video cameras and with corresponding mathematical formula. It leads to a simple formula that computes the height and the diameter of a cloud in a form like a cylinder which is transformed to a cuboid with corresponding volume. A similar procedure has been published in Apikayan et al 2008 (see article of Yaar) [3] for the height of the cloud. A more sophisticated procedure is included in HOTSPOT [4] or has been presented by Armand [1], where the initial cloud consists of 10 different layers. The range of the explosive mass within these experiments varies between 0.5 and 100 kg of PETN.

Figure 1 and 2 shows as an example for the video slides with optical marks to calibrate the size of the cloud. The coloured dots represent cloud height (green) and cloud width (red). The magenta dots represent a fixed distance on the ground that was used to calibrate the cloud size. [The slides have been provided in an internal report from GRS, Cologne [5]]. Figure 1,right slide, shows the experiment with 25 kg explosives and 20 l isopropanol, which should simulate a detonation of a car with a fuel tank. It can be seen clearly, that this additional load leads to a higher cloud due to the thermal energy from the explosion of isopropanol. This will shift the activity concentration in the lowest layer to smaller numbers.

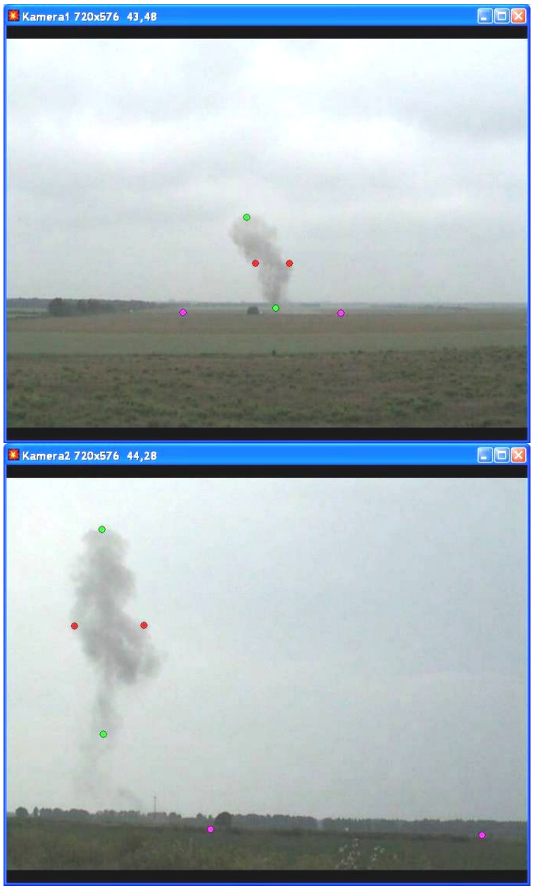

Fig. 1: Experiments with 50 kg explosives (left) and with 25 kg explosives and isopropanol (right). The coloured dots represent cloud height (green), cloud width (red) and a fixed distance on the ground for photogrammetrical analysis (magenta). The thermal heat of isopropanol gives an addition to the height of the cloud.

As a result of all the experiments in 2003 and 2007 a fit function (Fig. 2) has been derived [5] that enables the user of the dispersion models simply to enter the amount of the explosives and get as a result the dimension of the initial cloud. The dispersion model uses this volume as a source term and starts to compute the meteorological dispersion of the particles in the cloud in downwind direction.

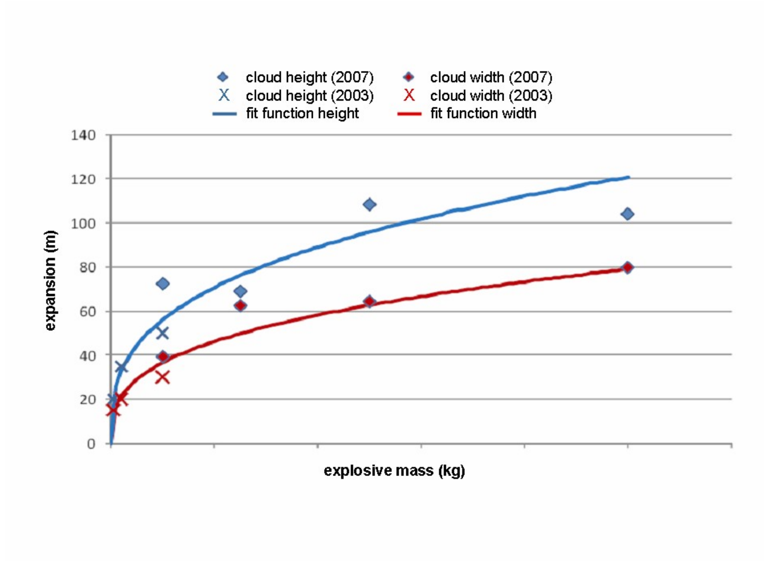

Fig. 2: Cloud height and width as a fit function from the two explosive experiments at the German Army test site in Munster (2003) and in Meppen (2007) [5].
(The amount of explosives in the figure must not be published for confidential reasons).

3. AEROSOL SPECTRA FOR DIFFERENT MATERIAL AFTER AN EXPLOSION

To run a decision support system some basic information for the input has to be provided. Basically this input consists of the meteorological data for the computation of the dispersion, the amount of the explosive and about the radionuclide and its activity.

However there is only sparse information about what happens to a certain kind of radionuclide after it is exploded into the atmosphere. Therefore a research programme has been conducted to study these effects. Several radionuclide surrogates together with explosive material have been brought to explosion. The following samples have been used:

- metallic sample
  Cu in form of a cylinder, pellets, granulate and powder
  Co in form of pellets, chips and powder,
  MbSe in form of a cylinder.

- ceramic sample
  ZrO_2, Y_2O_3, Ceramofix in form of cylinders and pellets.

- liquid samples
  CeO_2-suspension, $YbCl_3$-solution and $BaSO_4$-suspension (Barilux®).

- powder samples
  CsCl, TiO_2 .

The samples have been used with and without a metal sleeve. As explosive material Seismoplast (based on PETN) und CompositB with an amount of 30 g, 50 g, 150 g, 300 g and 450 g has been used. After the explosion the resulting aerosols and/or fragments have been collected and the spectral distribution of the radionuclide surrogate has been analysed.

The research programme has been conducted by three institutions (TÜV Süd, Fraunhofer EMI, Fraunhofer ITEM) [6]. It still is in progress and will end in autumn 2011; therefore only preliminary results can be provided at the moment. These are:

- The fraction of respirable aerosols depends very much on the size of the metal sample. From the copper powder or copper granulate a fraction of less than 5 % is dispersed into the atmosphere, from copper pellets roughly 1 % and from massive copper cylinder roughly 0.5 %.

- The fraction of respirable aerosols from liquids differs from 10 % to 50 %.

- The fraction of respirable aerosols from ceramic material differs between roughly 0.1 % and 50 % depending on the compressive strength of the material.

After finishing the research programme, these results can be used as an input pre-processor in dispersion models in the next future. The user just has to enter the form of the radionuclide and will get a simple proposal on the aerosol spectra distribution of the material after the explosion. The model can use this information directly and will compute the deposition to the ground or the inhalation dose more realistic as in the past, where mainly 100 % of respirable aerosols have been assumed for conservative reasons.

4. THE DECISION SUPPORT SYSTEME LASAIR

Conducted by the German Federal Office for Radiation Protection (BfS) and in charge of the German Federal Ministry for Environment, Nature Preservation and Reactor Safety (BMU) the programme LASAIR [7] has been developed which is able to give a first and rapid overview of atmospheric dispersion, ground activity, deposition and different exposition pathways (inhalation, ground- and cloudshine) after an instant release of radioactive material. The systems programme can be used by radiation emergency authorities that are responsible for emergencies within the different German States. The programme has been developed in the year 2000 and was continuously upgraded until now.

LASAIR has been used in various exercises and has proved to be a valuable tool for decision makers as well. In April 2008 the latest version 3.0.9 has been released. Because of the implemented topographical maps LASAIR is intended to be used

basically in Germany but can be applied as well in other countries using general available geobrowsers. LASAIR is based on the Lagrangian particle simulation of an existing systems programme (LASAT) [8, 9, 10] and has been adjusted especially to meet the requirements for handling a “dirty bomb” scenario. It covers presently a simulation area of maximum 40 x 40 km^2.

Special attention has been directed to the usage of the programme in emergency cases. The programme can be run on a Laptop, is extremely easy to handle and allows the user only a strictly straight forward step by step usage in order to grant a maximum security feeding the programme with input data.

5. APPLICATION OF LASAIR FOR DIFFERENT SOURCE TERMS AND DIFFERENT AEROSOL SPECTRA

In order to study the effects from both different source terms and different aerosol spectra a suitable scenario has been chosen. The scenario should take place in a German harbour, where containers have been unloaded from a cargo ship. Terrorists might have smuggled a dirty bomb in a container and the bomb will explode after the container has been unloaded. Meteorological conditions are a moderate wind from the seaside and a neutral stability class.

Figure 1 shows two cases for the source term. In the left figure the source term is a single point source where as in the right figure the source term shows the cloud after the explosion of 100 kg. The output parameter from LASAIR is the inhalation dose resulting from a certain amount of Cs 137. It can be seen, that the main difference of both source terms is in the close vicinity of the explosion area, where the single point source leads to a significant higher inhalation dose (approx. factor 30). The total affected area is rather similar. The smaller inhalation dose is due to the fact, that a higher amount of explosives has a bigger updraft of the radionuclide material and therefore the activity concentrations in the lowest layer of the model, where the inhalation dose is computed, is much smaller for the realistic scenario with a volume source.

The results indicate, that the information on the vertical distribution in the atmosphere of the radionuclides is essential and more data are needed in order to get a even better understanding of the vertical distribution. This could be achieved by further experiments and the help of special meteorological measurement system, e.g. as the LIDAR (Light Detection and Ranging).

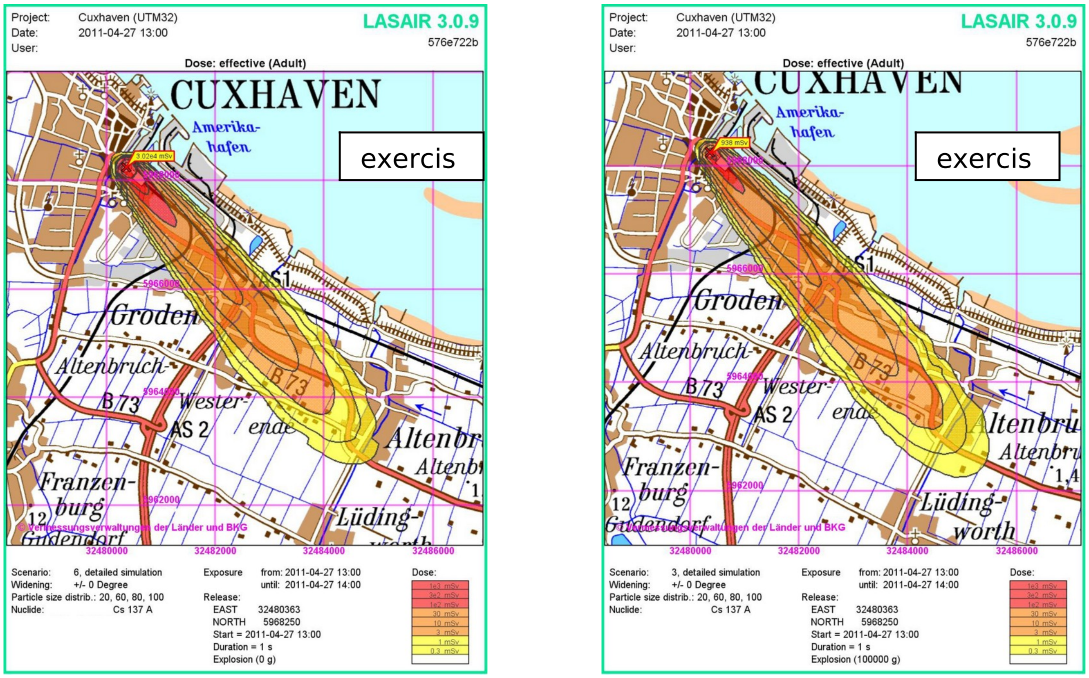

Fig. 3: Simulation of a “Dirty Bomb” exploding at a German harbour with dispersion from a single point source (left) and from a volume source (right) after an explosion of 100 kg. Output parameter is the inhalation dose, radionuclide is Cs 137.

It is emphasised that the amount of activity in these simulations has been increased artificially in order to make the effect of the different source terms much more obvious.

The same scenario has been used for studying the effects of different aerosol spectra. In a first simulation (Fig. 4, left figure) the spectra has been chosen as realistic according to the outcome of the research programme. The spectral distribution is 5 % of the material is in a range of 0 – 2.5 µm, 5 % in a range of 2.5 – 10 µm, another 5 % between 10 – 50 µm and 85 % of the material has a larger diameter as 50 µm. In the second simulation (Fig. 4, right figure) the spectra has been chosen rather unrealistic in such a way that 100 % of the material would be respirable.

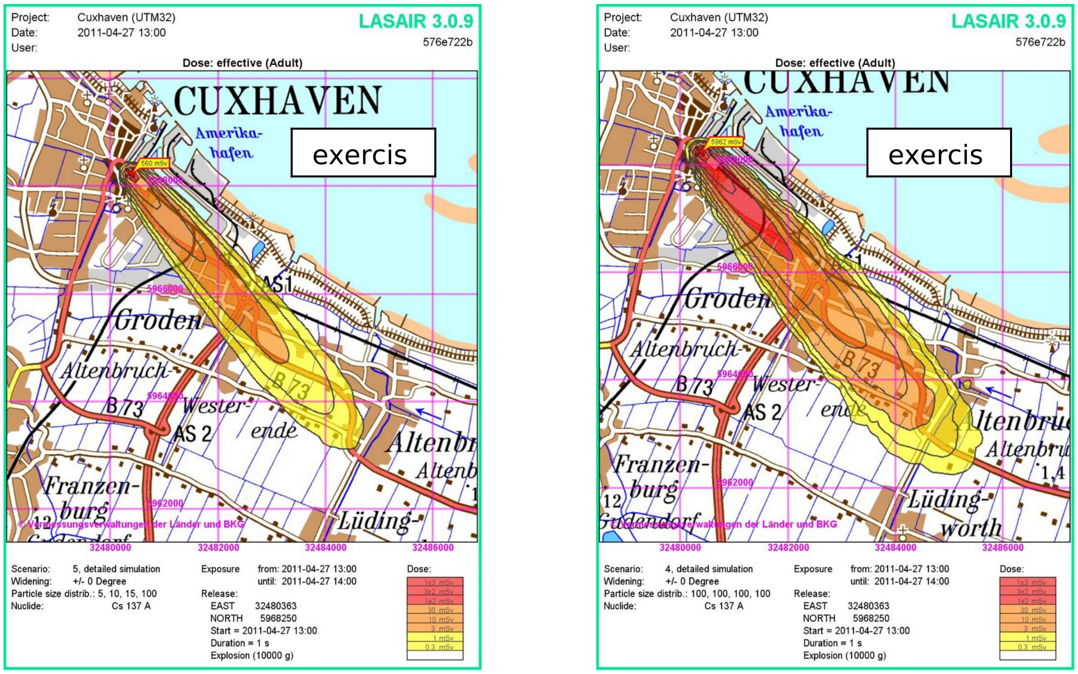

Fig. 4: Simulation of a “Dirty Bomb” exploding at a German harbour. Figure left shows dispersion from particle with different aerosol diameters, figure right shows dispersion with particles completely respirable.

The results from LASAIR show, that the realistic scenario with the real spectral distribution of the aerosols in this special case leads to a lower inhalation dose (roughly factor 10) in comparison to the conservative scenario with 100 % respirable aerosols as well as to a smaller affected area. Depending on the physical consistency of the radionuclide an even higher factor for the difference between realistic and conservative approach can be assumed.

Both scenarios show rather clearly that the close vicinity of the explosion area needs the highest interest for decision makers as the significant doses are very likely only in a few kilometres distance. From this point of view, the planned reduction of the grid size within LASAIR from 25 m to 5 m and a more detailed consideration of buildings become evident.

6. SUMMARY

To cope with a dirty bomb scenario answers have to be provided quickly and clean. A decision support system (LASAIR) has been developed since several years and has proved its ability during various applications and exercises in the scope of dirty bomb-scenarios to answer relevant questions. It's a simple tool that is very easy to handle and needs only basic relevant meteorological and radiological input information.

The model LASAIR uses a volume source term as an initial cloud that has been deduced from explosion experiments as well as specific aerosol spectra derived from various small scale explosion experiments. It can be seen from the application of both input parameters to a specific scenario that the results become much more realistic.

The simulations show as well, that special interest should be laid to the close vicinity of the explosion site as the main part of the activity, deposition and consequently the dose is relevant only to a downwind distance of only a few kilometres.

7. ACKNOWLEDGEMENTS

The German Ministry for Defence has supported the explosive experiments that took place at WTD 91 in Meppen in 2007 and GRS, Cologne has conducted the analysis of the cloud dimensions. This support has led to a deeper understanding of the development processes of the initial cloud in the atmosphere after an explosion and is highly appreciated.

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